

Advanced Technology Imperative For The E&P Industry

Keynote Address

by
Myron Gottlieb
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Abstract

1996 was a very good year for the E&P industry. But, in spite of the higher wellhead prices reached in 1996, natural gas prices are expected to remain constrained to around \$2.00/Mcf real, for the foreseeable future. This leads to a projected lower-48 natural gas demand of about 29 Tcf by 2010, with production coming from increasingly more difficult environments (onshore gas >15,000 feet deep, offshore Gulf of Mexico gas, and tight formation gas). In fact, these more difficult environments are projected to deliver nearly all the 7 Tcf of increased production projected for year 2010.

A key assumption in all of the major energy supply/demand projections is that advanced technology will enable increasing quantities of natural gas to be recovered at costs consistent with the constrained wellhead prices projected. This will require continued RD&D investment by all industry stakeholders. In short, the industry is challenged to produce a greater quantity of natural gas from increasingly more difficult environments at constrained wellhead prices. Advanced technology must play a key role in meeting this challenge. And, the E&P industry must invest the appropriate resources, manpower and funds, to assure that the pace of technology advances is adequate to bring about the significant improvements in technology that are projected to contribute to the industry's future.

Introduction by Hugh D. Guthrie

(FETC Senior Management and Technical Advisor)

Introducing our next speaker will be the Director of FETC's Fuels Resources Division, which includes the natural gas area. He happens to be our only representative from Desert Storm. I would be remiss if I didn't say this is someone I have come to know well as a person. I have a great deal of respect for Dr. Lawson. He will now introduce Myron Gottlieb.

Introduction by William F. Lawson, Jr.

(Director, FETC Fuels Resources Division)

Thank you very much, Hugh, for those kind words. It is my great pleasure today to introduce Dr. Myron Gottlieb, Vice President and General Manager of the Supply Business Unit of the Gas Research Institute. He directs GRI's broad program of finding, producing, and treating natural gas. Myron is a chemical engineer by profession, and during his distinguished career he has held responsible positions in industry, academia, and government, where he was, some years ago, in the Office of Fossil Energy. In our frequent discussions, Myron and I focus on the synergy of GRI's and DOE's natural gas programs. We work to achieve a strong and appropriate coordination of those programs. Our organizations share many technical goals. Indeed, many of the projects presented at this conference receive support from both GRI and DOE. Today, Myron will present his views on the advanced technology imperative in the E&P industry. Please welcome and give your kind attention to Dr. Myron Gottlieb.

Address by Myron Gottlieb

Well, Bill, I was hoping you would take a cue from Sandra's introduction of Commissioner Matthews and introduce me as the handsome and charming Myron Gottlieb! Also, I want to thank the last three speakers for giving my presentation today! With your permission, I will give you an abbreviated presentation, because much of what I have to say was said very eloquently by the last three speakers.

The three major topics I will touch on today deal with (1) future trends for natural gas in the U.S. marketplace and the role of advanced technology in this future, (2) the environment for continued RD&D, and (3) an example of how advanced technology can contribute to cost-reduction in the E&P industry.

Future Trends for Natural Gas and the Role of Advanced Technology

This was a very good year, of course, for the E&P industry. Prices recovered from past years' lows. They even spiked to about \$4.50 on the spot market. But in spite of that, the average price of natural gas over the past year was on the order of \$2.25 an Mcf; and oil was about \$18 per barrel. These prices are still, of course, a far cry from the very high prices seen in the mid-1980s. They are significantly below the \$2.50 price that is seen as the floor needed for reserve expansion by two-thirds of the producers that have recently been surveyed by Arthur Andersen.

Looking toward the future, natural gas prices, as you heard today, are expected to remain constrained, on the order of \$2.00 an Mcf real. This is consistent with the GRI baseline projection; it is consistent, as you heard, with the EIA projection; and it is consistent with the targets that producers are using to evaluate their business opportunities. At these constrained

prices, demand is projected to increase in the lower-48 to about 29 Tcf by 2010, from 22 Tcf today. This production is going to come from increasingly more difficult environments: onshore deep gas (gas greater than 15,000 feet deep), offshore Gulf of Mexico gas, and tight-formation gas. In fact, the increase from these three difficult environments is projected to make up almost the entire 7 Tcf of increased production.

Looking at the regional characteristics of this production, GRI's 1997 Baseline projects that the traditional Southwest production will decline, with significant growth in tight formations of the East and the Rockies, and even greater growth in the Gulf offshore region. GRI's projection and other major projections for increased natural gas production at constrained prices have one major assumption imbedded in their details. The assumption is that advanced technology will be developed to enable gas recovery costs to clear the market hurdles. This, of course, will require continued RD&D investment by all stakeholders. I would like to stress that the industry reliance on advances in technology is fundamental to the belief, and the confidence, that producers *will* be able to meet increased demand at constrained prices.

The magnitude of the technology challenge is indicated by this example from the GRI Baseline Projection. This slide shows three important economic parameters: reserve additions per well, reductions in lower-48 drilling, and success rates. The future requires about a 50-percent increase in reserve additions per well, compared to 1994. If this improvement is to be achieved, new technology will need to be developed to help producers cost-effectively find and drain reservoirs, so that on average they deliver 50 percent more gas from each well than delivered today.

Drilling costs today represents about 40 percent of average well cost. As you see here, the drilling cost index is also projected to decrease significantly, despite the recent trend toward cost increase brought about by pressure for more drilling. New technology will also be required to sustain the success rates for wells targeted in the more difficult environments of the future.

The challenge, then, is to maintain the aggressive pace of performance improvements over the next decade through development and commercial introduction of new E&P technology.

The 1996 NPC report characterized the situation by saying, "The E&P industry faces significant challenges to exploiting new reservoirs at acceptable costs." and "Developing advanced technology is a strategic imperative for the E&P industry." In fact, the industry has done very well in reducing cost, in recent years, as you have heard today. For example, from 1991 to 1995, reserve replacement cost has been reduced from about \$5.50 per barrel of oil equivalent to \$4.00, with an even greater reduction associated with new additions. The question is: What will happen in the future, and will that trend in cost reduction, or even cost stabilization, continue?

The importance of advanced technology was also highlighted by Arthur Andersen in their 1996 study of major cost factors that indeed contributed to cost reduction. They identified three factors. The first factor, which you already heard today, contains three specific technologies: seismic, drilling, and fracturing. The second factor is access to new supply frontiers, including coal seam resources and deep water. In fact, access to these frontiers is based on the availability

of technology that made these frontiers economic for production. The third factor is business-related, and that is the “just-in-time” production strategy. Here I will take a lesson from Dr. Lay, and take some bragging rights! GRI has made major contributions to two of these technologies highlighted as important to the industry’s capability: coalbed methane and fracturing technology. I will talk about fracturing technology in a few moments.

The Downward Trend in E&P R&D Investment

The pace of technology development must continue unabated into the future if the E&P industry is to meet the increased demand for natural gas. What is the environment for this? You heard several views today on what the environment looks like. I am going to show you data that suggest that they were right. The growth in industry R&D spending has abated, with the trend now flat to negative. Federal government R&D, of course, has gone down over the last several years. Looking at research intensity by industry sector, we see that energy R&D investment, as a percentage of sales, trails other industry sectors by far. As an aside, but one view of the importance of the R&D data to industry leaders, let me relate my experience on trying to obtain more current information. I tried to update this 1994 data with the 1995, and perhaps the 1996, statistics, but couldn’t find it in *Business Week*. I called *Business Week*. They told me that, for lack of interest, this statistic is no longer developed. The survey has been terminated. I assume it is CEOs and other industry leaders who read *Business Week*. I will let you come to your own conclusion about their interest in R&D and the impact on industry.

The direction of E&P R&D investment is captured by this slide. Although this includes both E&P and refinery research, the downward direction is uncontested. The majors have reduced their in-house R&D significantly. Service company R&D has remained stable-to-slightly-growing as they have responded to the increase in outsourcing.

The constrained investment in R&D is expected to continue because individual producers have found that they are generally unable to capture the economic benefits from R&D. In large part, this is due to the large cost associated with R&D and the inability of any one producer to amortize this cost against their market share. As you probably know, the largest producer of natural gas produces less than 5 percent of the total natural gas market.

The downward pressure in R&D expenditure is also driven by the interest that you have in your investment funds and I have in mine. It is driven by our interest in the next quarter financials. So we are responsible in large part for putting the pressure on the companies to, in fact, worry about the next quarter financials and perhaps under-invest in R&D. Moreover, the money that is being invested in R&D, as you heard, has a much nearer-term focus than in the past. This has an important implication: breakthrough technology is not as likely to be developed in the future. And it is, of course, breakthrough technology that has had the major impact in reducing E&P cost.

On the positive side, the E&P industry has become more efficient and more productive in R&D expenditure, in part due to greater collaboration among organizations. This greater collaboration is driven by the need to spread the R&D cost and risk. But it has a number of

advantages beyond that. It allows one to access a wider array of expertise and field data. It allows one to rapidly change course in response to business conditions, especially if it is done through contract research. If the collaborating organizations are in tune with their members needs, it also allows for the systematic and aggressive transfer of technology.

The electronic revolution has also had a major impact on the efficacy of research. It is interesting, at least to me, to point out that the revolution in the electronics industry is the result of massive investment in computer-technology R&D by the government and by industry. Computer technology is, in effect, a result of collaboratively-funded research. And, does the advent of this significant technology represent a one-time event? Perhaps. But, it is not clear what emerging technology will have the same impact over the next decade.

Coming down here on the plane, I was reading the *Journal of Petroleum Technology*. The Journal contained an editorial by William J. Pike, who can add to this issue. I would like to quote parts of his editorial. He wrote, "many people are questioning both the state of R&D and the upstream industry and its future. Recent conversations have emphasized the danger that we now face. By some estimates, as much as 70 percent of R&D funding may have dried up over the past decade. That which is left is most-often directed at near-term targets." He goes on to say that "we are now enjoying the fruits of research, much of it results-oriented, conducted more than a decade ago. It is difficult to believe that we will enjoy the same luxury ten years from now, unless something is done soon." The real issue here, that all of us who are in the industry should be facing, and all of the thought-leaders of the industry should be facing, is to assess the appropriate level of RD&D needed to develop technology vital to meet the industry objective—the objective of meeting increased demand and increased production at constrained wellhead prices.

How Advanced Technology Can Contribute to Cost Reduction in E&P

Now I would like to present one concrete example of how collaborative R&D can contribute to major E&P cost reduction. I will use an example from the GRI program. Shown here are the major elements of the GRI program, which in 1997 is funded at \$38 million. The example I will site is directed at hydraulic fracturing. Recall that this was one technology pointed out by Arthur Andersen as being a major contributor to E&P cost reduction.

This is an important technology. There are 20,000 fracturing jobs pumped per year. It is an almost \$1 billion-a-year market. Gas wells account for 75 percent of that on a dollar basis. Job costs range from \$15,000 to a quarter of a million. For those who may not be familiar with hydraulic fracturing, the goal of hydraulic fracturing is to place a fracture in the pay zone to allow hydrocarbons to migrate more easily from the formation to the wellbore. The fracture is created

in the formation by pumping fluid at high pressure down the wellbore through perforations into the pay zone.

In the early 1980s, when GRI initiated R&D in this area, conventional wisdom suggested that fractures grew mainly in the pay zone, confined above and below by high stress barriers. But after more than a decade of RD&D, it was found that conventional wisdom was mostly in error. In fact, fractures are most likely to grow outside of the pay zone, entirely wasting all the cost associated with the fluid that is placed outside of the pay zone and all the cost associated with the massive horsepower it requires to pump that fluid.

This finding didn't come easily. It is the result of more than ten years of comprehensive RD&D. It is a result of over \$70 million of collaborative expenditure through the Gas Research Institute. It is the result of at least an equal amount of cofunding to GRI by the industry and government, and it is the result of active participation of industry through GRI's formal advisory bodies and through contracts to industry, government, and academia. The product of the research is a large portfolio of technology that allows producers to effectively design and execute an economic hydraulic fracture. A central part of this technology is the real-time fracture model and instrumentation system that allows producers to evaluate and make real-time modifications to the fracture as it propagates.

The impact of this technology is reflected in several hundred case histories that we have documented. Shown here are the results from just six companies, representing over 100 wells. The impact manifests itself in two ways. First, it shows up by suggesting producers can conduct smaller jobs at less cost, while achieving about the same production. Or, the technology suggests that at equivalent cost, you can redesign the job to improve production. As you can see, Company F on the far right did not get a cost saving. But, by using this technology effectively, they increased production by about 200 percent. Company E achieved about a 50-percent cost reduction, and they did have about the same production. The cost advantage is determined by reservoir characteristics, and, in most cases, the impact is a combination of the two.

These case histories support GRI's projection that, by the year 2000, this technology will enable the industry as a whole to experience a cost reduction of more than \$240 million in lower-48 operations. This \$240 million is associated only with the gas applications. There are applications in oil and, of course, there are international applications. Clearly, investment in R&D can reap major economic rewards.

In summary, we see a low-price energy future. Advanced technology is vital to growth of the natural gas market. It will help deal with the constrained wellhead prices projected, and it is needed to bring about economic production from more difficult producing environments. We expect that there will be continuing downward pressure on technology-development budgets. It is a real challenge to the industry to find the equilibrium between lower R&D budgets and higher R&D productivity, and to make sure that the appropriate amount of technology is indeed developed to meet the industry's goals. In any case, R&D productivity must increase through greater collaborative RD&D and capitalizing further on the electronic revolution. In short, advanced technology is indeed a strategic imperative for the E&P industry. Thank you.

Questions and Answers

Question by Thomas Williams of Westport Technology Center

International. GRI is taking the lead in pushing an R&D tax credit in Congress right now. One reason is the advancement of R&D, and the limited dollars, and the use as a tax incentive. Could you provide an update on that? Recently, TIPRO (Texas Independent Producers and Royalty Owners Association) endorsed it, as well a couple of other E&P associations. A lot of us in the oil and gas industry are extremely interested in seeing this tax incentive pass, so that it can spur additional research dollars.

Response by Myron Gottlieb. Sandra, I know you are involved in this. Would you like to comment?

Response by Sandra Waisley (Acting Deputy Assistant Secretary for Oil and Gas, DOE Headquarters). The Office of Fossil Energy has been working with GRI and EPRI to evaluate a proposal they came up with. It is still being evaluated, though. Arthur Andersen conducted a cost-benefit analysis of a proposal. It is in the works and they would like to have it incorporated in legislation this year. We at DOE would like to support this proposal, but I really can't say anything more than that. Two years ago, there had been some cost-benefit analysis on the structure of this proposal, and now they have to update that. If anyone is really interested in this, call me, or call the GRI office in Washington. We could probably give you a better update in a couple of weeks.

Comment by Myron Gottlieb. Sandra, isn't this initiative an improvement on the current tax credit?

Response by Sandra Waisley. It is an improvement, because the existing tax credit is based on just incremental R&D above a base level. They would like to get a much more aggressive tax credit that is not based on incremental levels each year, but on total collaborative research that is ongoing—have a 100-percent tax credit.

Closing by Hugh Guthrie

Thank you, Myron, and thanks to all of the speakers. I think this last comment illustrates what a dynamic world we live in. As I look back over my 54 years in the oil and gas industry, it seems we have ever-recurring challenges. I think that in the future, the ever-recurring challenge will be as demanding as any I have witnessed in my time. I want to stress again how important cooperation is. We work closely with GRI, and a big advantage is that it provides us the opportunity to participate in advisory groups that give constant feedback to GRI on where their priorities should lie, and this, in turn, can give us a sense of our priorities. Thank you all for coming.

ADVANCED TECHNOLOGY IMPERATIVE FOR THE E&P INDUSTRY



Myron Gottlieb
Gas Research Institute

TOPICS

- **Future Marketplace for Natural Gas**
- **Environment for RD&D**
- **Examples of Advanced E&P Technology**
- **Summary**

PRODUCER PROFITS

“Unocal’s Profit Triples in Third Quarter”
Los Angeles Times, 10/24/96

“Mobil and Arco Report Earnings Growth”
New York Times, 1/28/97

**“Shell Oil Rides Higher Prices,
Production to Post Record Earnings for Third Quarter”**
Oil Daily, 10/23/96

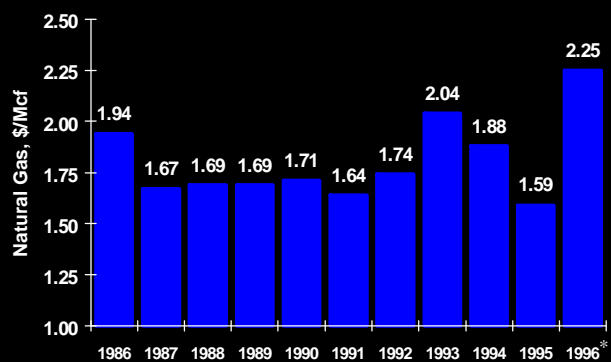
**“Profit Grew 17% in Quarter With Gains at Conoco
Unit”**
Wall Street Journal, 10/24/96

“Amoco Logs Record Quarterly, Annual Profits ...”
Oil Daily, 1/23/97

**“Texaco Chief Says Company is Aligned for Growth;
Company Increases Earnings Expectations ...”**
Business Wire, 12/4/96

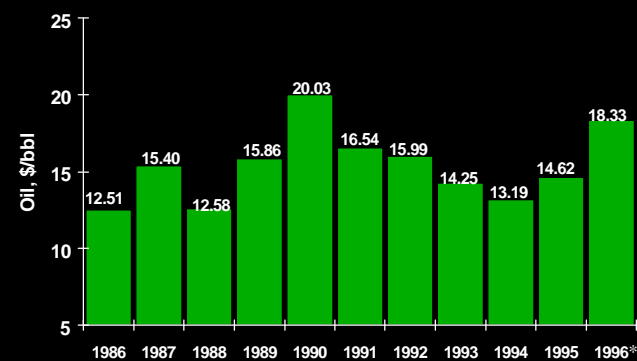
AVERAGE U.S. O&G WELLHEAD PRICES (Nominal Dollars)

GAS



* Estimate

OIL



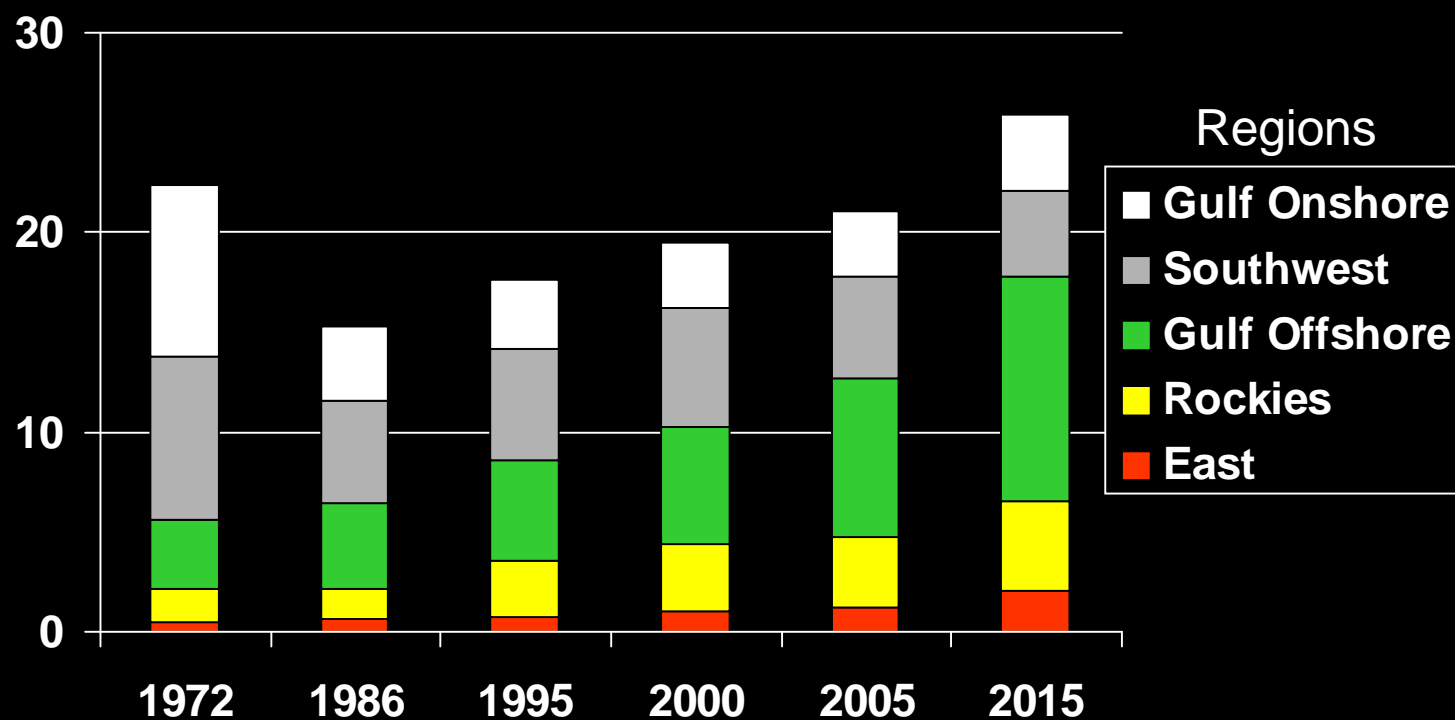
* Estimate

Ref: 1/6/97 Oil & Gas Journal

THE U.S. NATURAL GAS FUTURE

- **Constrained Wellhead Prices Into the Next Decade**
 - \$2/Mcf (1996)
- **Demand Increasing to 29 Tcf in 2010**
 - 22 Tcf in 1996
- **Increasing Production From Difficult Environments**
 - Onshore Deep (Greater Than 15,000 Ft) Gas ~300%
 - Offshore Gulf of Mexico ~200%
 - Tight Formations ~20%

LOWER-48 GAS PRODUCTION (TCF)



KEY ASSUMPTION IN SUPPLY-DEMAND PROJECTIONS

- **Advanced Technology *Will Be Developed* to Enable Gas Recovery Costs to Clear Market Hurdles**
 - **Requires Continued RD&D Investment by All Stakeholders**

FUTURE TECHNOLOGY CHALLENGE

(Year 1994 to Year 2010)

	<u>1985</u>	<u>1990</u>	<u>1994</u>	<u>2000</u>	<u>2005</u>	<u>2010</u>
• 50% Increase in Reserve Additions Per Gas Well (Bcf/Well)	0.97	1.38	1.70	2.41	2.79	2.55
• 30% Reduction in L-48 Drilling Cost Indices (1988 = 1)						
– Onshore	1.17	1.07	0.85	0.76	0.67	0.62
– Deep Water Gulf	1.36	0.92	0.87	0.73	0.62	0.58
• Maintain L-48 Success Rates						
– Exploration	24.8	25.4	34.2	26.2	28.4	30.9
– Development	79.3	82.1	83.2	82.3	83.3	84.3

Ref: 1997 GRI Baseline Projection

E&P INDUSTRY CHALLENGE

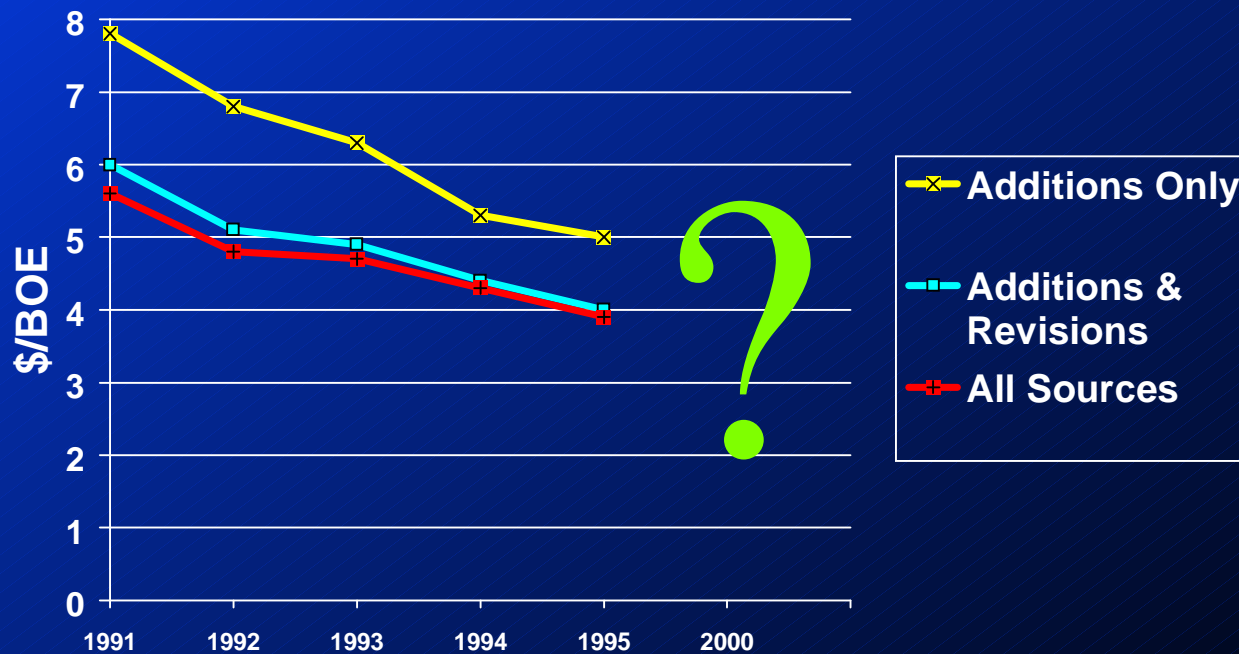
- Produce Increasing Quantities of Natural Gas From Increasingly Difficult Environments at Constrained Wellhead Prices

NPC Report

- “The ... (E&P) ... Industry Faces Significant Challenges to ... (Exploiting) ... New Reserves ... at Acceptable Costs”
- “Developing Advanced Technology is a Strategic Imperative for the E&P Industry”

SIGNIFICANT COST-CUTTING ACHIEVED IN 1990's

DECREASING RESERVE REPLACEMENT COSTS



Source: Arthur Andersen Oil & Gas Reserve Disclosures Database
Ref: Oil & Gas Investor, July 1996

SIGNIFICANT COST-CUTTING ACHIEVED IN 1990's

MAJOR COST-CUTTING FACTORS

- **“Three Factors Have Contributed to ... (Reduced Gas Costs).**
 - **First, the Advent of Better Seismic, Drilling, and Fracturing* Technologies ...**
 - **Second, ... New Supply Frontiers ... Including Coal Seam Gas* and the Deepwater ...**
 - **Third, ... (Reduced Costs From) ... “Just-in-Time” ... Strategies.**

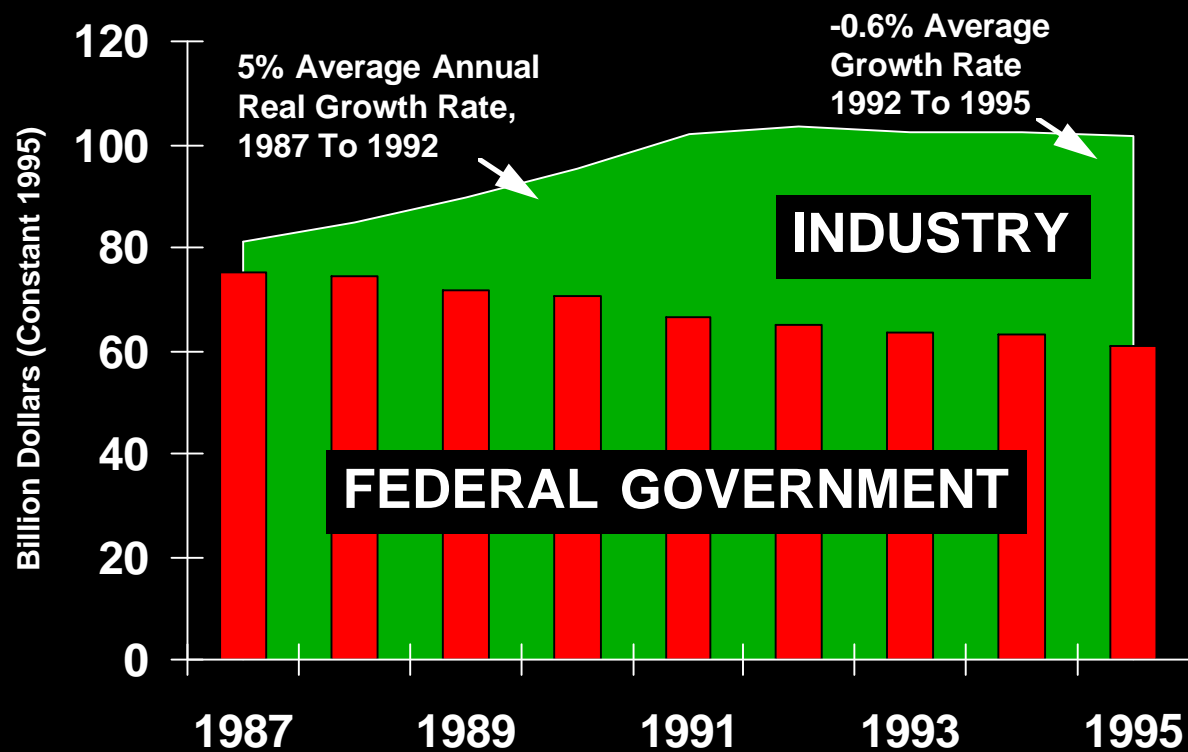
*** Significant GRI Contributions**

Ref: North American Natural Gas Trends (1996)
Arthur Andersen and Cambridge Energy Research Associates

ENVIRONMENT FOR DEVELOPMENT OF ADVANCED TECHNOLOGY

RECENT TRENDS IN R&D EXPENDITURES

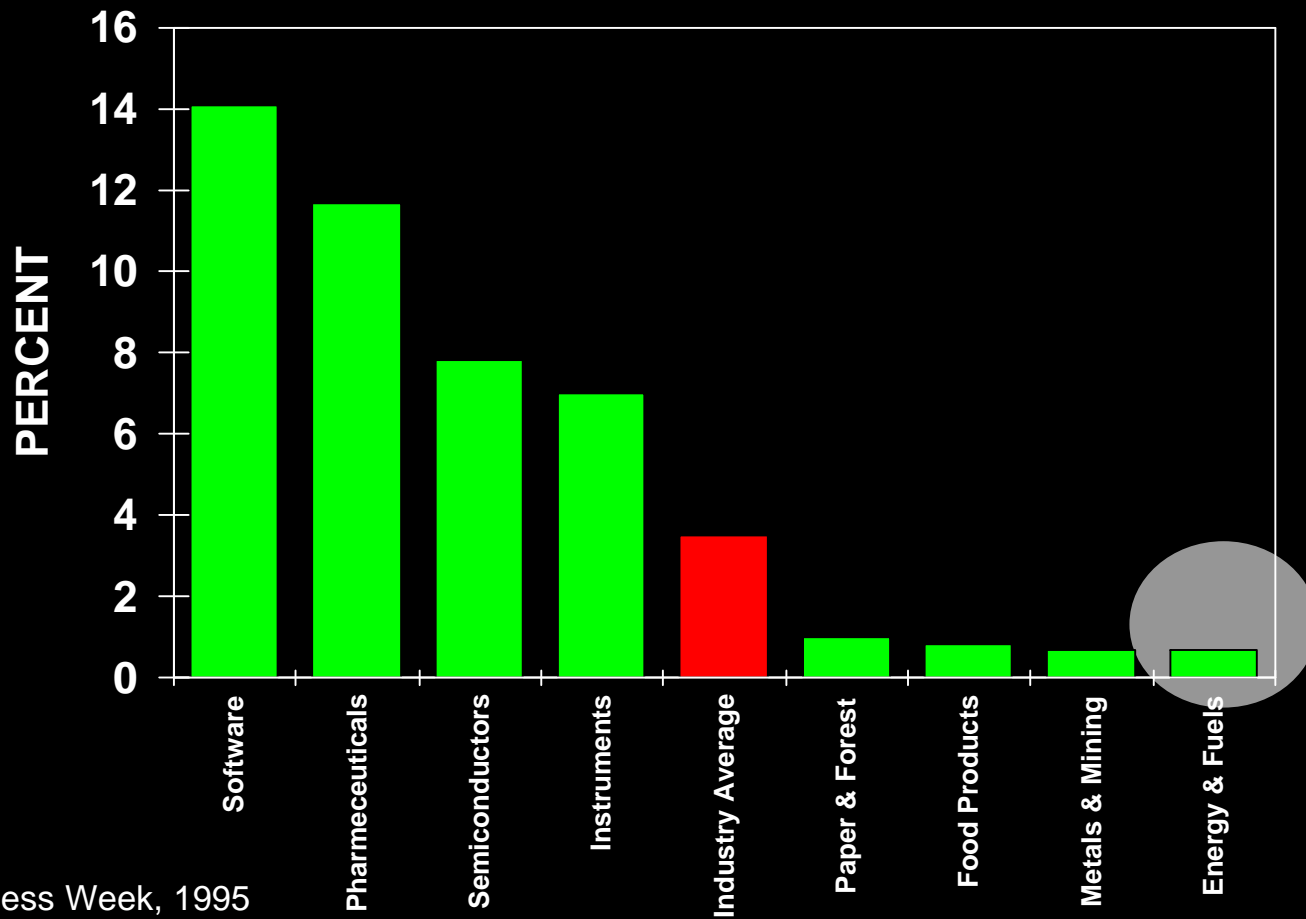
- *Industry R&D is Declining*
- *Federal Government R&D is Declining Significantly*



Source: Corporate R&D in Transition; DOE, March 1996

INDUSTRIAL RESEARCH INTENSITY, 1994

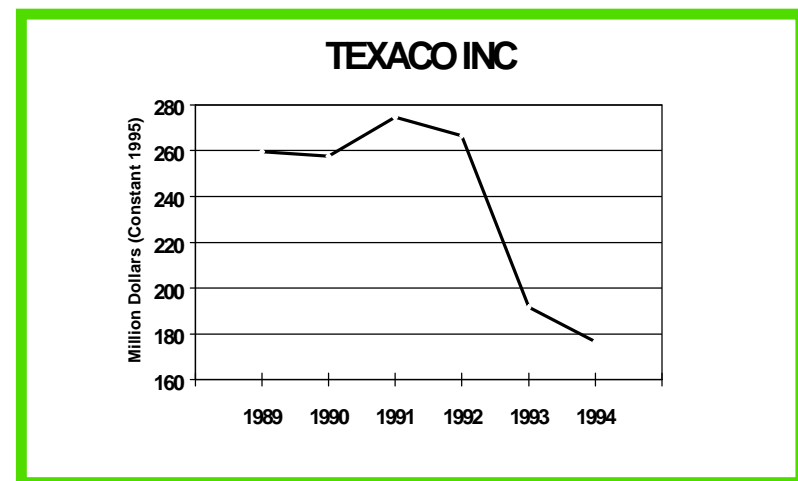
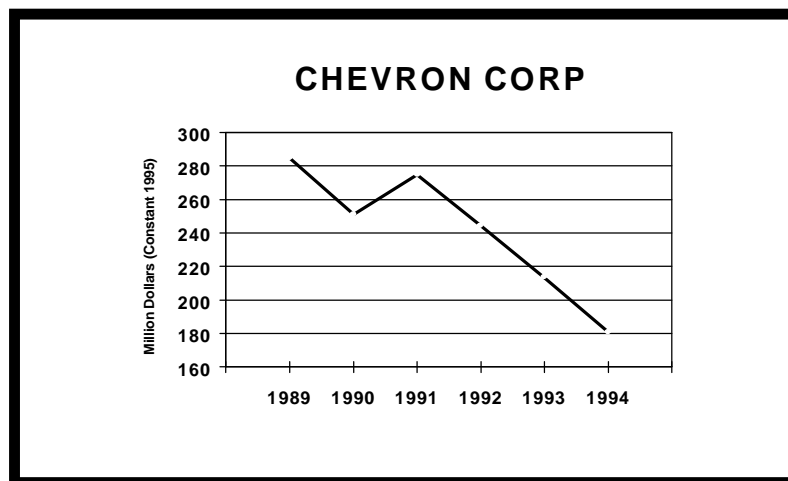
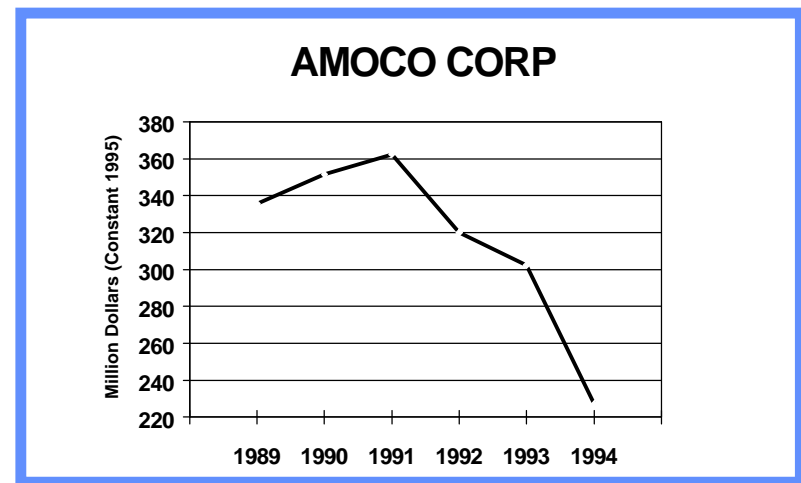
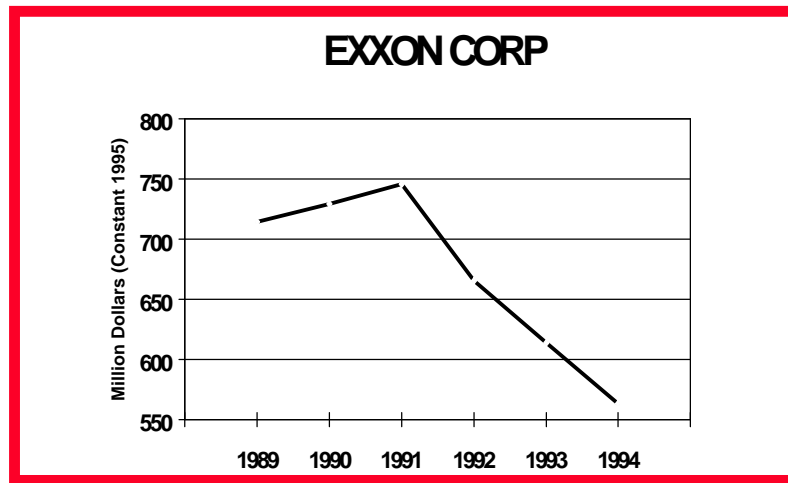
R&D Expenditures as a Percent of Sales



Source: Business Week, 1995

R&D SPENDING IN DECLINE IN EARLY 1990'S

Four Major Energy Producers



Source: Schonfeld and Associates 1995, 1994

TRENDS IN TECHNOLOGY DEVELOPMENT STRATEGY OF THE E&P INDUSTRY

- **Constrained Investment Relative to Past**
 - **Inability to Capture Economic Benefits**
 - **Driven by “Next Quarter” Financials**

TRENDS IN TECHNOLOGY DEVELOPMENT STRATEGY OF THE E&P INDUSTRY

- **Nearer-Term Focus**
 - **Evolutionary vs Revolutionary Development**
 - **Less Basic Research**

TRENDS IN TECHNOLOGY DEVELOPMENT STRATEGY OF THE E&P INDUSTRY

Greater Collaboration Among Organizations

- **Advantages**
 - **Spreads R&D Costs and Risks**
 - **Accessibility to Wide Array of Expertise and Field Data**
 - **Ability to Respond to Rapidly Changing Business Needs**
 - » **Relates Mainly to RD&D Conducted Through Contracts**
 - **Promotes Technology Transfer**
 - » **Systematically Exposes Supporters to Advanced Technologies**
 - » **Can Provide Support for Short Courses, Forums, Workshops**

References:

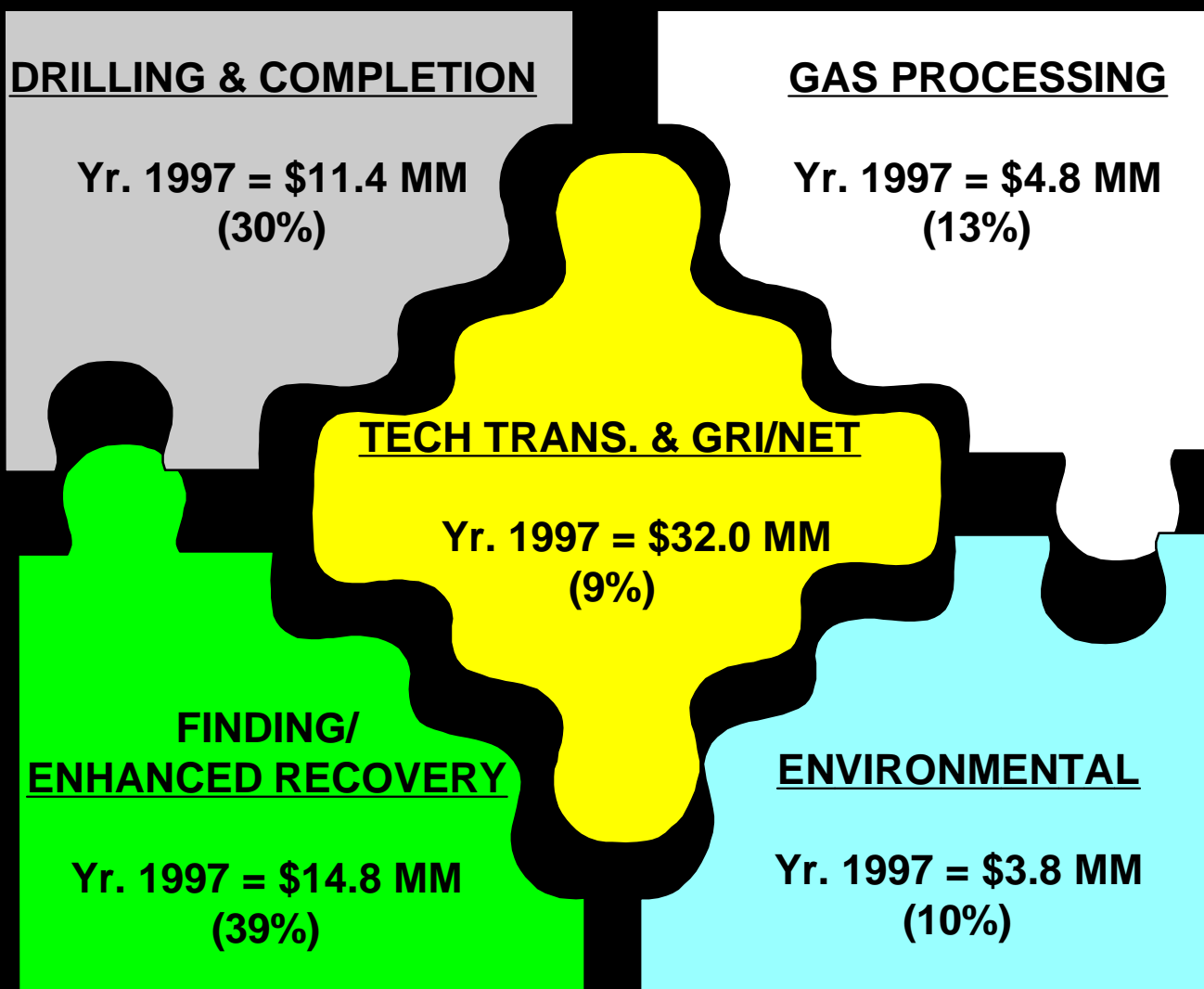
- “Choosing an R&D Consortium,” Souder, W.E. and Nassar, S., Research Technology Management (March-April 1990)
“Does Consortium Research Belong in My Business Strategy?” Gottlieb, M., JPT (June 1994)

TRENDS IN TECHNOLOGY DEVELOPMENT STRATEGY OF THE E&P INDUSTRY

- **Increased Productivity Through Electronic Revolution**
 - **Data Handling and Analysis**
 - **Modeling**
 - **Communication**

GRI'S APPLIED R&D FOR SUPPLY E&P

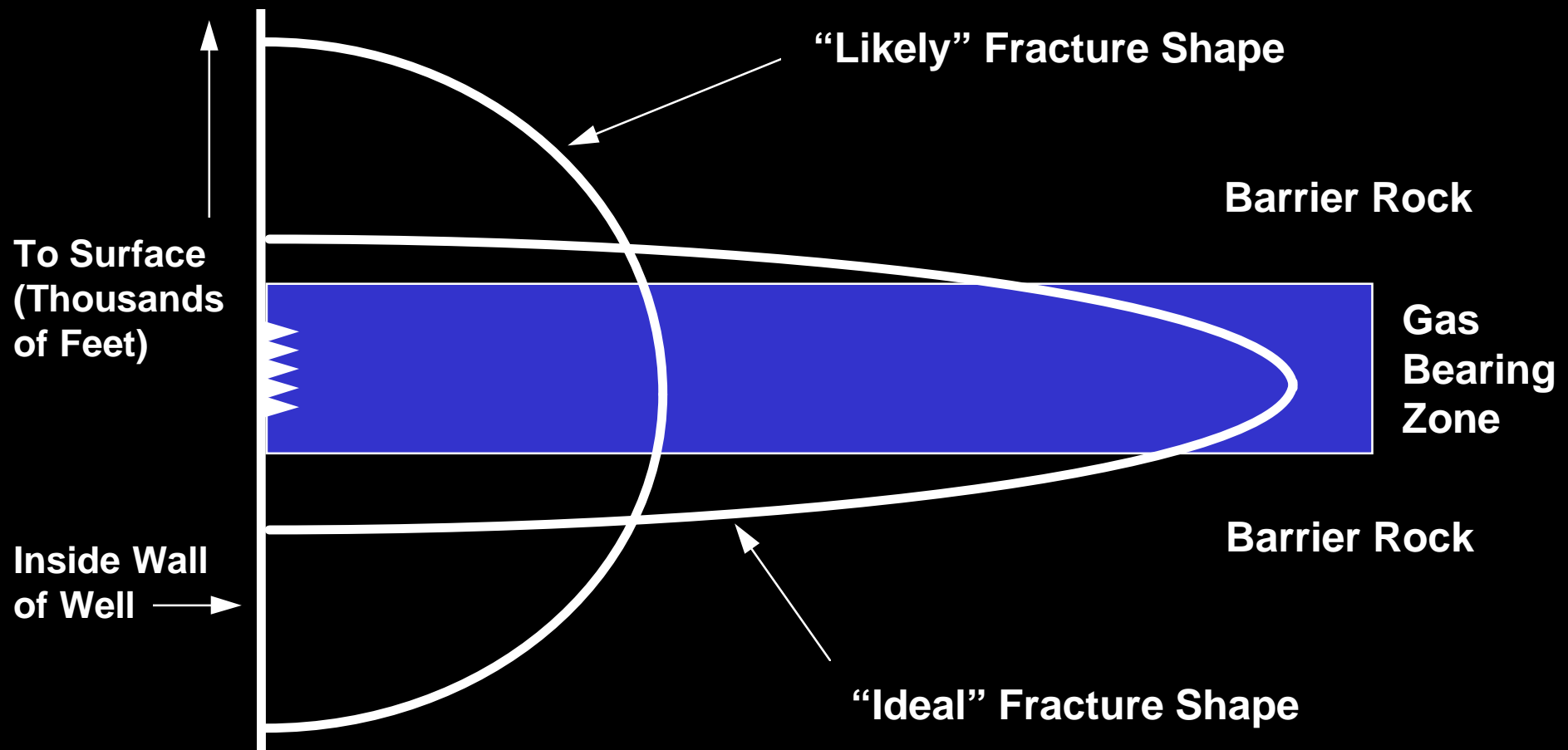
Year 1997 = \$38 Million



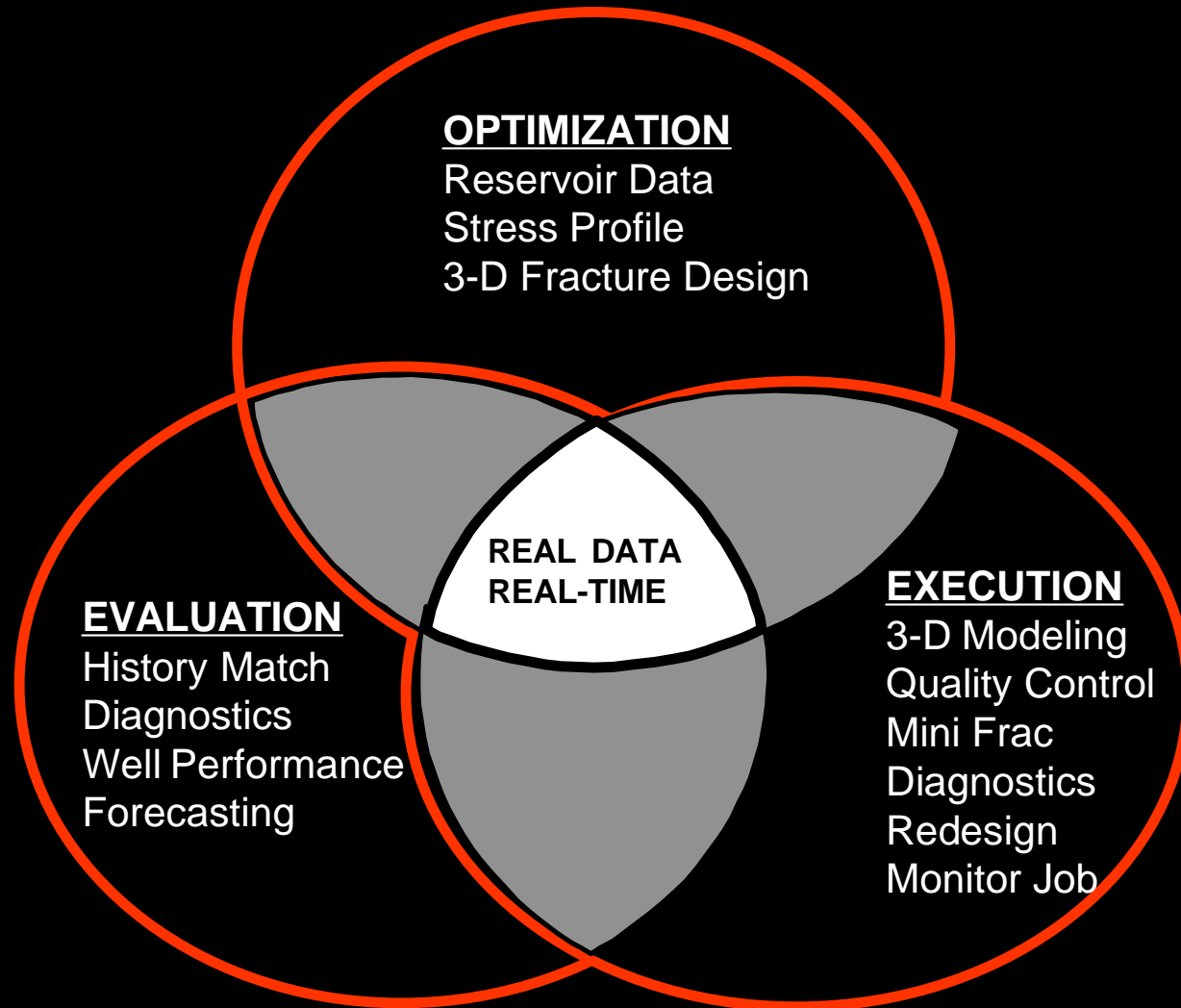
LARGE INDUSTRY INVESTMENT IN FRACTURING

- **20,000 Frac Jobs Pumped Per Year**
 - **\$860 Million/Year Market**
 - **Gas Wells Account for 75% of the Market in \$**
 - **Job Costs Range from \$15,000 to \$250,000**

GRI RESEARCH DETERMINED THAT FRACTURE SHAPE IS “NON-IDEAL”



IMPROVED HYDRAULIC FRACTURING PROCESS



AST PROVIDES SUBSTANTIAL BENEFITS

Percent



ADVANCED STIMULATION TECHNOLOGY (AST)

- **Deployment Case Histories Support Projection: \$240 MM
Cost Savings in Year 2000**
 - 20% Reduction in Cost of Fracture Job
 - 25% Increase in Production

SUMMARY

- **Low Price Energy Future**
- **Advanced Technology is Vital to Growth of the Natural Gas Market**
 - **Constrained Exploration and Production Costs**
 - **Needed Production From Increasingly Difficult Environments**
- **Continuing Downward Pressure on Technology Development Budgets**
- **R&D Productivity Must Increase**
 - **Greater Collaborative RD&D**
 - **Capitalize on Electronic Revolution**